# OPERATING COST OF PUBLIC SERVICES AND CITY SIZE. RESULTS FROM THE COMBINED ANALYSIS OF PER CAPITA AND PER UNIT OF INFRASTRUCTURE SPENDING RATIOS


## ABSTRACT

Many studies have shown that some factors related to city population such as the economies or diseconomies of scale, the variations in the urban pattern linked to the city size, the special conditions of the urban environment in large cities or the changes in the level of service directly impact on the unit operating cost of urban public services. However, research has not been able to isolate their real influence, and, even, in that direction they work. As a result, the relationship between the city population and the unit operating cost of their public services remains unclear: some authors state that the unit operating cost of public services decreases when the population increases; others that it increases or that it follows a U-Shaped function with an optimal city size. For a sample of 4.875 Spanish municipalities, the combined analysis of per capita and per unit of infrastructure expenditure ratios has allowed to delve into the central role of two of the aforementioned factors: the level of service and the urban pattern. Thus, for the services of public lighting, water supply, sewage and sanitation, waste collection and disposal, parks and pavements maintenance and street cleaning, higher levels of per capita spending have been found both in municipalities under 1.000 and above 50.000 inhabitants. However, in the smallest municipalities, the higher level of spending per inhabitant is boosted by a less compact urban pattern, whilst in the largest cities the reason would be a better level of service.

## INTRODUCTION

Many studies have tried to delve into the relationship between the city size and the operating cost of its public services. However, research has not been able to identify undoubtedly what determinants of public services operating cost are correlated to city size, their real influence and, even, in what direction they work. In this sense, factors such as the presence of economies or diseconomies of scale, the variations in the urban pattern linked to the city size, the special conditions of the urban environment in large cities or the changes in the level of service have been the most analyzed. As a result of all the forces involved, some authors have concluded that the unit operating cost of public services decreases when the population increases; others, yet, stated that it increases or that the unit operating cost follows a U-Shaped function with an optimal city size from the public spending point of view. In addition, the results reached in the studies may be difficult to compare, since four unit spending ratios can be analyzed - per capita, per dwelling, per unit of developed area and per unit of infrastructure/service – and each of them represent a very different concept, what is very evident in those services based on the operation of a physical infrastructure. In this context of uncertainty, and due to the unstoppable global urbanization process, it is crucial to continue delving into the understanding of the role of city size in the economic efficiency of the urban public services.

The aim of this study has been to analyze whether the unit operating cost of a set of property-oriented services is largely influenced by city size and, specifically, by two qualitative factors usually very difficult to model such as the level of service and the dispersion of the infrastructures throughout the territory (urban pattern). With this purpose, for a sample of 4,875 Spanish municipalities, the evolution of the per capita and per unit of infrastructure expenditure ratios regarding the city population has been analyzed for the services of street lighting, water supply, sewage and sanitation, waste collection and disposal, street cleaning and parks and pavements maintenance. This analysis allows to know to what extent the taxpayer´s effort (per capita expenditure) translates into a better level of service, using as a *proxy* the operating cost per unit of infrastructure/service. On the other hand, from both the spending unit ratios, it can be obtained the ratio of infrastructure per inhabitant -dispersion of public services throughout the territory- and its correlation with the city population.

The study has been structured as follows. Firstly, a review of the literature on the relationship between the size of the urban settlements and the operating cost of their public services has been included, followed by the description of both the methodology and data origin and elaboration. Afterwards, the results obtained are presented for the services of public lighting, water supply, sewage and sanitation, waste collection and disposal, street cleaning and parks and pavements maintenance, together with their critical discussion. Finally, the main conclusions of the study are summarized.

## LITERATURE REVIEW

Many studies, usually carried out within the framework of research about the optimal size of urban systems from the economic (Arnott, Stiglitz 1979; Camagni et al. 2013) or administrative (Soukopová et al. 2014; Fahey et al. 2016) point of view, have tried to determine which factor related to the number of inhabitants of an urban settlement drives the unit operating cost of public services in one or another direction. However, due to the complexity of the urban ecosystem, most researchers have faced significant difficulties both to identify what public expenditure determinants are correlated with city population and to isolate their real impact.

Among the determinants of public services' operating cost closely related to city size, the most widely analyzed, undoubtedly, is the reaching or not of economies of scale in large cities (Dollery et al. 2008). Thus, some studies have shown that the existence of fixed administrative or operational costs can lead to lower per capita operating cost from a certain population threshold (Oates 1985; Allers, Geertsema 2016). However, this result is far from unanimous (Boyne 1995). For example, for other authors these economies of scale are exhausted after a certain city population level (Solé-Ollé, Bosch 2005; Breunig, Rocaboy 2008) or, even, diseconomies of scale could appear due to a greater functional complexity and administrative inefficiency in large cities (Boyne 1996; King, Ma 2000). Moreover, there are studies where no relevant economies of scale for per capita spending have been found (Blom-Hansen et al. 2016; Harjunen et al. 2017). In addition, a higher demand for public services and therefore spending in large cities (Buettner and Holm-Hadulla 2013) can be confused with scale diseconomies. As a result, the analysis of the presence of economies of scale in comprehensive operating cost studies is very complicated.

If public services are analyzed individually, the results of the classic study conducted by Hirsch (1968) are usually confirmed. This study concludes that the labor-intensive services (social services, education, etc.) usually have diminishing returns with respect to their size, whilst those services involving the operation of a fixed infrastructure would benefit from the economies of scale (Dollery, Fleming 2006). For example, for waste collection and disposal, Stevens (1978), Dubin and Navarro (1988), Boyne (1996) and Bel and Mur (2009) have found that both operating cost per dwelling and per inhabitant quickly decrease when population increase in small urban settlements, whilst economies of scale would be lost in cities with a greater number of inhabitants. However, for Bohm et al. (2010) those economies of scale are maintained, although they are less robust, in larger cities. Regarding the water cycle, Termes-Rifé et al. (2013) found economies of scale for operating cost per inhabitant in water sanitation and purification plants, although Fraquelli and Giandrone (2003) indicated that they would be greater in the smaller cities (until 100.000 inhabitants). Moreover, according to Guo et al. (2014), these economies of scale would not be transmitted to the operating cost of water and sewage networks' maintenance. As indicated, in more labor-intensive services such as the park and gardens maintenance (Martínez-Vázquez, Gómez-Reino 2008) or public lighting (Benito et al. 2020), economies of scale do not tend to be effective, except for street cleaning (Byrnes, Dollery 2002). Although simpler than those involving a plurality of services, these studies also have limitations that compromise the results obtained. Probably the most prominent is the differentiation between economies of scale and density (Tran et al. 2019), since the areas with the highest density usually appear only in the larger cities (Stevens 1978; Holcombe, Williams 2008). In these cases, there is an overlap between the scale and urban pattern impact which is difficult to tackle. Furthermore, it is also difficult to differentiate between the effects of economies of scale and range, since large cities can employ professionals able to provide a wide scope of efficient services (Dollery, Fleming 2006).

A second determinant of the unit operating cost of public services linked to city size is the level of service. As is logical, the unit operating cost of any service will largely depend on its characteristics (Duncombe, Yinger 1993). In any case, it is a very difficult to control qualitative variable in quantitative studies. For this reason, in most of the cases *proxy* variables have been used not to measure the variable itself, but to control its variation. For example, following the classical theory of Tiebout (1956), Reingewertz (2012) has tried to associate, with much difficulty, variations in service levels with aspects such as changes in housing prices, immigration patterns, the number of births or the real estate market health. As can be seen, these approximations are not very direct (Harjunen et al.

2017). Regarding the relationship between population size and level of service, many studies have concluded that smaller municipalities are more capable of adapting the latter to the preferences of their citizens (Oates 1972; Rodríguez-Pose, Gill 2003). However, if a correlation between city population and level of service is performed, the results are diffuse, mainly because the effects of the variation in service levels can be confused, among others, with policy factors. For example, according to Denters et al. (2014) the relationship between operating cost and service level (efficiency) could be better in small municipalities given the better control of spending, while other studies such as Brueckner (1982), Craig (1987) and Oates (1988) conclude that large municipalities could provide a greater range of services with the same per capita expenditure as smaller municipalities. However, this could not be the result of greater efficiency, but of the decrease in service levels due to the lack of competition in the production of public services (Bergstrom, Goodman 1973; Reingewertz 2012).

A third set of factors linking city population and the unit operating cost of public services would be those related to the special social environment of large cities. Although some of these factors such as congestion, the higher rates of crime and vandalism (Glaeser, Sacerdote 1999) and the greater inequalities and poverty levels (Alesina et al. 2000; Borge, Rattso 2004) affect the city as a whole and could be linked to diseconomies of scale, there are determinants directly related to the performance of the operating cost as the higher wages in large cities (Glaeser, Maré 2001).

Finally, the operating cost of public services is linked with the urban pattern, basically due to the influence of the dispersion of population and infrastructures throughout the territory (Carruthers, Ulfarsson 2008; Hortas-Rico, Solé-Ollé 2010; Bel 2012). Since, as indicated, the densest urban patterns are located almost exclusively in large cities, this factor is somewhat correlated with city population. This fact is especially decisive for services operating a physical infrastructure, the so-called services "to property" (Mace 1961) where the operating cost largely depends on the size of the infrastructure (Stone 1973) and would be less determinant in the people-oriented services. For instance, in services "to property", a low spending ratio per unit of infrastructure is likely to be coincident with a high spending ratio per inhabitant under urban sprawl conditions. For these reasons, most of the studies analyzing the mergers of different administrative structures, both at the local and regional levels, have concluded that the changes in the administrative structure have no influence on spending levels if the physical units of provision of services are not modified (Boyne 1995; King, Ma 2000; Blom-Hansen et al. 2016; Roesel 2017). In addition, whilst the physical infrastructures are essentially fixed, the population is variable over time, inducing a significative fiscal stress in shrinking cities (Moss 2008; Radzimski 2016).

The urban pattern as a whole is a very difficult qualitative factor to manage in quantitative studies (Borcherding, Deacon 1972; Carruthers, Ulfarsson 2003; Fregolent, Tonin 2016). Thus, this factor is usually represented in engineering studies by variables such as the housing density or the length of roads per urbanized hectare (Garrido-Jiménez et al. 2018), whilst in many econometric studies the *proxy* selected is the population density, usually available in most of the usual public databases. It should be noted that this *proxy* can lead to incorrect results, since the population density within a fixed administrative border, leads to a false increase in compactness with any increase in the number of inhabitants (Ladd 1992; Andrews 2015). These differences also contribute to the divergence among studies of different nature.

As can be observed, the vast majority of the studies carried out have reached their conclusions from the operating cost per capita analysis (Narbón-Perpiñá, De Witte 2018a, 2018b), which, as indicated, brings about important limitations to manage the role of many variables, among them qualitative variables such as the level of service and the urban pattern (Moisio, Uusitalo 2013; Blom-Hansen et al. 2016).

# MATERIALS AND METHODS

## Study objective

As indicated, the relationship between the unit operating cost of public services and the number of inhabitants of an urban settlement is usually explained from factors such as economies of scale, the social and environmental particularities of large cities, the urban pattern, or variations in the level of service. However, studies usually approach this field from the analysis of one spending ratio, which, does not allow to capture the complexity of the relationship between the urban variables involved. Through the combined analysis of per capita and per unit of infrastructure/service spending ratios, the aim of this study has been to delve into the role of the urban pattern and level of service, crucial factors in those services involving the operation of a physical infrastructure, and usually misrepresented in studies based exclusively in the analysis of per capita spending ratios.

## Methodology

To achieve this objective, for a sample of 4.875 Spanish municipalities, the operating cost ratios both per capita and per unit of service/infrastructure have been estimated for the services of public lighting, water supply, sewage and sanitation, waste collection and disposal, parks and gardens maintenance, street cleaning and pavement maintenance. As indicated, the operating cost per unit of infrastructure could be a good *proxy* for the level of service, and, in addition, the quotient between both ratios, representative of the amount of infrastructure or service per inhabitant, may help to assess the role of population dispersion in the spending levels (Carruthers, Ulfarsson 2003). Indirectly, the analysis of spending trends can help to identify possible threshold jumps (Malisz 1972). The ratios to be estimated will be those indicated in Table 1:

**Table 1. Operating expenditure and unit of infrastructure/service ratios**

| Ratio | Elaboration | Unit |
|---|---|---|
| Operating cost per inhabitant | $\text{Operating cost of service} / \text{Number of inhabitants}$ | €/inhabitant/yr |
| Operating cost per infrastructure/service unit | $\text{Operating cost of service} / \text{Number of service units}$ | €/unit/yr |
| Infrastructure per inhabitant | $\text{Number of service units} / \text{Number of inhabitants}$ | Ud/inhabitant |

The data necessary to carry out this study come from the Database of the Effective Cost of Services Provided by Local Entities elaborated yearly by the Spanish Ministry of Finance since 2014. This database has the particularity that, apart from the municipal population and the annual expenditure for each service, it also contains the dimensions of the basic infrastructures at municipality level. Other variables included in database as the management form of the service (direct, service contract, etc.) have not been considered because the literature has not shown a conclusive relationship between these variables, the unit operating cost of the service and the number of inhabitants in the municipality.

Despite its potential, this database has some limitations. The first is that not all municipalities have provided the data required by the Ministry, which means that the database is composed of only 4,875 of the 8,131 Spanish municipalities. Furthermore, not all services are equally represented, since many municipalities have submitted only part of the documentation. The second and most important limitation is that the data provided by the municipalities do not have further validation or quality control by the Ministry. Due to this issue, a series of adjustments for statistical purposes have been necessary. Firstly, null or impossible values have been removed. Secondly, inconsistent values have been eliminated through a Chauvenet test. Finally, municipalities with fewer than 100 inhabitants have not been included in the study due to the greater probability to find spending singularities (Solé-Ollé, Bosch 2005). Even considering all these aspects, the sample is representative enough for all the services and population levels, as can be observed in Table 2:

**Table 2. Sample size by service and population range. Percentage regarding whole Spanish municipalities**

| Inhabitants | Public Lighting | Water Supply | Sewage | Waste Collection Disposal | Parks Maintenance | Street Cleaning | Pavements Maintenance | Total Spain Municipalities by size |
|---|---|---|---|---|---|---|---|---|
| 100-1.000 | 1774 | 1596 | 1339 | 525 | 833 | 1299 | 1301 | 3606 |
| | (49) | (44) | (37) | (15) | (23) | (36) | (36) | |
| 1.000-5.000 | 1105 | 877 | 745 | 448 | 676 | 857 | 684 | 1822 |
| | (61) | (48) | (41) | (25) | (37) | (47) | (38) | |
| 5.000-20.000 | 605 | 413 | 408 | 344 | 546 | 533 | 396 | 888 |
| | (68) | (47) | (46) | (39) | (61) | (60) | (45) | |
| 20.000-50.000 | 195 | 159 | 155 | 146 | 179 | 172 | 155 | 267 |
| | (73) | (60) | (58) | (55) | (67) | (64) | (58) | |
| >50.000 | 111 | 86 | 81 | 88 | 101 | 101 | 90 | 149 |
| | (74) | (57) | (54) | (59) | (68) | (68) | (60) | |
| TOTAL | 3790 | 3131 | 2728 | 1551 | 2335 | 2962 | 2626 | 6732 |
| | (56) | (47) | (41) | (23) | (35) | (44) | (39) | |

As shown, so as to carry out the study the municipalities have been classified according to the population ranges established by the Spanish Local Act to assign them responsibilities, which will help to analyze the results (better than the aggregated equations and regression coefficients) considering that the small municipalities are overrepresented. In any case, a comprehensive statistical analysis has been carried out to verify that the classification of municipalities by ranges of population is not a source of bias in the results. To perform the discrete unit of production of each service (Boyne 1995), among all the possibilities, the most representative of the final product (outcome) has been selected, discarding intermediate variables of production (outputs) (Boyne, Law 2005; Ahmad, Eijad 2011; de Kruijf, de Vries 2018). The unit representative of the outcome of each service are the following (Table 3):

**Table 3. Ratios of annual spending per infrastructure/service unit**

| Public Service | Physical variable of reference | Ratio of Annual Spending per infrastructure unit |
|---|---|---|
| Water supply | No. of dwellings | €/dw./yr. |
| Sewage and sanitation | No. of dwellings | €/dw./yr. |
| Waste collection and disposal | No. of dwellings | €/dw./yr. |
| Street cleaning | Road area ($m^2$) | €/$m^2$/yr |

| | | |
|---|---|---|
| Public lighting | Road length (m) | €/m/yr |
| Parks and gardens maintenance | Parks and gardens area (m²) | €/m²/yr |
| Pavements maintenance | Road area (m²) | €/m²/yr. |

# RESULTS

The results obtained for both spending ratios and the infrastructure/service per inhabitant ratio according population range are summarized in Table 4:

**Table 4. Spending and infrastructure ratios according to population range**

| Service | Ratio | Number of inhabitants | | | | |
|---|---|---|---|---|---|---|
| | | 100-1000 | 1000-5000 | 5000-20000 | 20000-50000 | >50000 |
| | Sample size (n) | 1774 | 1105 | 605 | 195 | 111 |
| Public lighting | | | | Average values | | |
| | Oper. Cost (€/inh./yr) | 73,02 | 46,68 | 32,74 | 27,47 | 27,31 |
| | Oper. Cost (€/m/yr) | 5,26 | 6,01 | 6,59 | 7,85 | 9,85 |
| | m/inhab. | 13,88 | 7,76 | 4,97 | 3,50 | 2,77 |
| | Sample size (n) | 1596 | 877 | 413 | 159 | 86 |
| Water supply | | | | Average values | | |
| | Oper. Cost (€/inh./yr) | 83,95 | 55,10 | 49,19 | 59,34 | 60,76 |
| | Oper. Cost (€/dw./yr) | 87,02 | 90,11 | 90,00 | 115,37 | 59,34 |
| | Dw./inhab. | 0,96 | 0,63 | 0,57 | 0,50 | 0,50 |
| | Sample size (n) | 1339 | 745 | 408 | 155 | 81 |
| Sewage and | | | | Average values | | |
| sanitation | Oper. Cost (€/inh./yr) | 15,58 | 11,71 | 12,72 | 12,41 | 16,60 |
| | Oper. Cost (€/dw./yr) | 16,44 | 20,33 | 25,68 | 26,62 | 33,41 |
| | Dw./inhab. | 0,95 | 0,58 | 0,49 | 0,47 | 0,49 |
| | Sample size (n) | 525 | 448 | 344 | 146 | 88 |
| Waste | | | | Average values | | |
| collection and | Oper. Cost (€/inh./yr) | 59,96 | 45,95 | 48,92 | 56,44 | 48,28 |
| disposal | Oper. Cost (€/dw./yr) | 60,55 | 72,01 | 85,42 | 110,76 | 96,60 |
| | Dw./inhab. | 0,99 | 0,63 | 0,57 | 0,50 | 0,50 |
| | Sample size (n) | 833 | 676 | 546 | 179 | 101 |
| Parks and | | | | Average values | | |
| gardens | Oper. Cost (€/inh./yr) | 27,43 | 18,49 | 18,67 | 21,72 | 28,34 |
| maintenance | Oper. Cost (€/m²/yr) | 6,58 | 6,13 | 4,26 | 5,72 | 4,77 |
| | m²/inhab. | 4,16 | 3,01 | 4,38 | 3,79 | 5,94 |
| | Sample size (n) | 1299 | 857 | 533 | 172 | 101 |
| | | | | Average values | | |
| Street cleaning | Oper. Cost (€/inh./yr) | 40,94 | 24,99 | 27,97 | 40,54 | 55,58 |
| | Oper. Cost (€/m²/yr) | 1,65 | 2,08 | 2,07 | 4,64 | 4,10 |
| | m²/inhab. | 24,81 | 12,01 | 13,51 | 8,73 | 13,56 |
| | Sample size (n) | 1301 | 684 | 396 | 155 | 90 |
| | | | | Average values | | |
| Pavements | Oper. Cost (€/inh./yr) | 75,46 | 46,55 | 37,81 | 24,83 | 24,72 |
| maintenance | Oper. Cost (€/m²/yr) | 2,65 | 2,50 | 3,31 | 4,24 | 11,41 |
| | m²/inhab. | 28,47 | 18,62 | 11,42 | 5,85 | 2,16 |
| Total | Oper. Cost (€/inh./yr) | 376,34 | 249,47 | 228,02 | 242,75 | 261,73 |

## RESULTS PER SERVICE

### *Street lighting*

For the public lighting service, the result for the expenditure ratios both per inhabitant and per unit of length of illuminated road is shown in Figure 1:

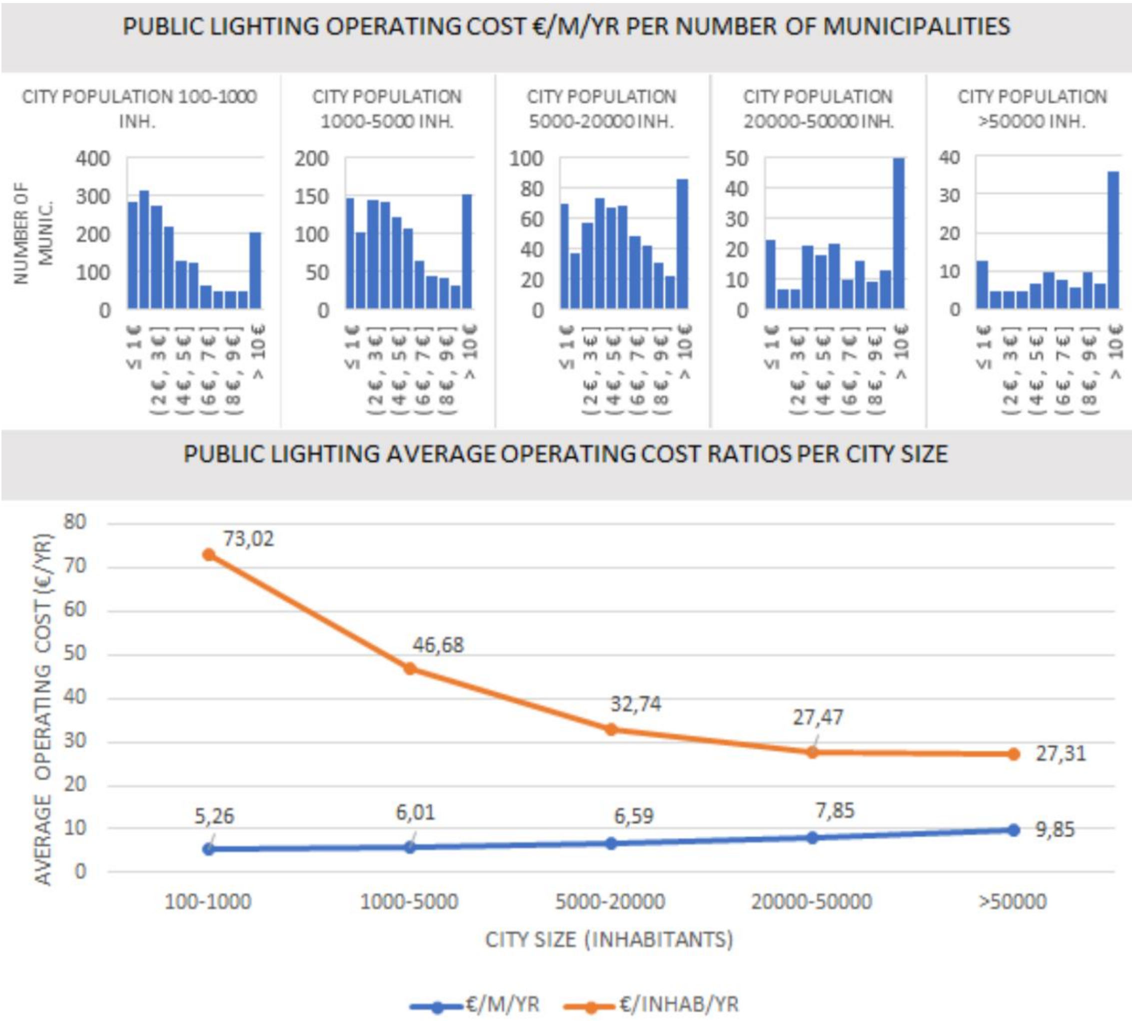


**Figure 1.-** Public lighting. Expenditure ratios per inhabitant and per length of illuminated street according to municipal population

The results show a significant divergence between both spending ratios. Whilst the operating cost per inhabitant decreases as the city size grows, especially in the smallest cities (quadratic function), the cost per unit of illuminated road rises steadily, being in the municipalities with population over 50.000 inhabitants (€ 9,85/m/yr) almost twice higher than in those with population under 1.000 inhabitants (€ 5,26/m/yr). It should be noted that the decrease in per capita expenditure in large cities is correlated with a lower ratio of illuminated street per inhabitant.

This result indicates that the greater compactness of large cities (Holcombe, Williams 2008) brings about more funds to maintain the infrastructure, even with less fiscal effort. Although part of these economic resources may be absorbed by higher wages in large cities (Glaeser, Maré 2001) or by greater vandalism (Ladd 1994), it is most plausible that the almost doubling of the operating cost per unit of infrastructure translates into a higher level of service.

***Water supply***

According to previous research, water per capita consumption is not expected to be highly influenced by city size (Morote 2017). As can be observed in Figure 2, the operating cost of the service per capita adopts the classic “U” shape, with lower spending average in municipalities with populations between 5.000 and 20.000 inhabitants. The high per capita spending level in smaller municipalities is very significant (+35% of increase compared to the next population step). Instead, the operating cost of the service per dwelling is somewhat erratic, remaining almost stable around 90 €/dwelling/year from 100 to 20.000 inhabitants, rising to 115,37 €/dwelling/year in cities with population between 20.000 and 50.000 inhabitants and falling significantly to 59,34 €/dwelling/year in cities larger to 50.000 inhabitants. This aspect is worthy of further research.

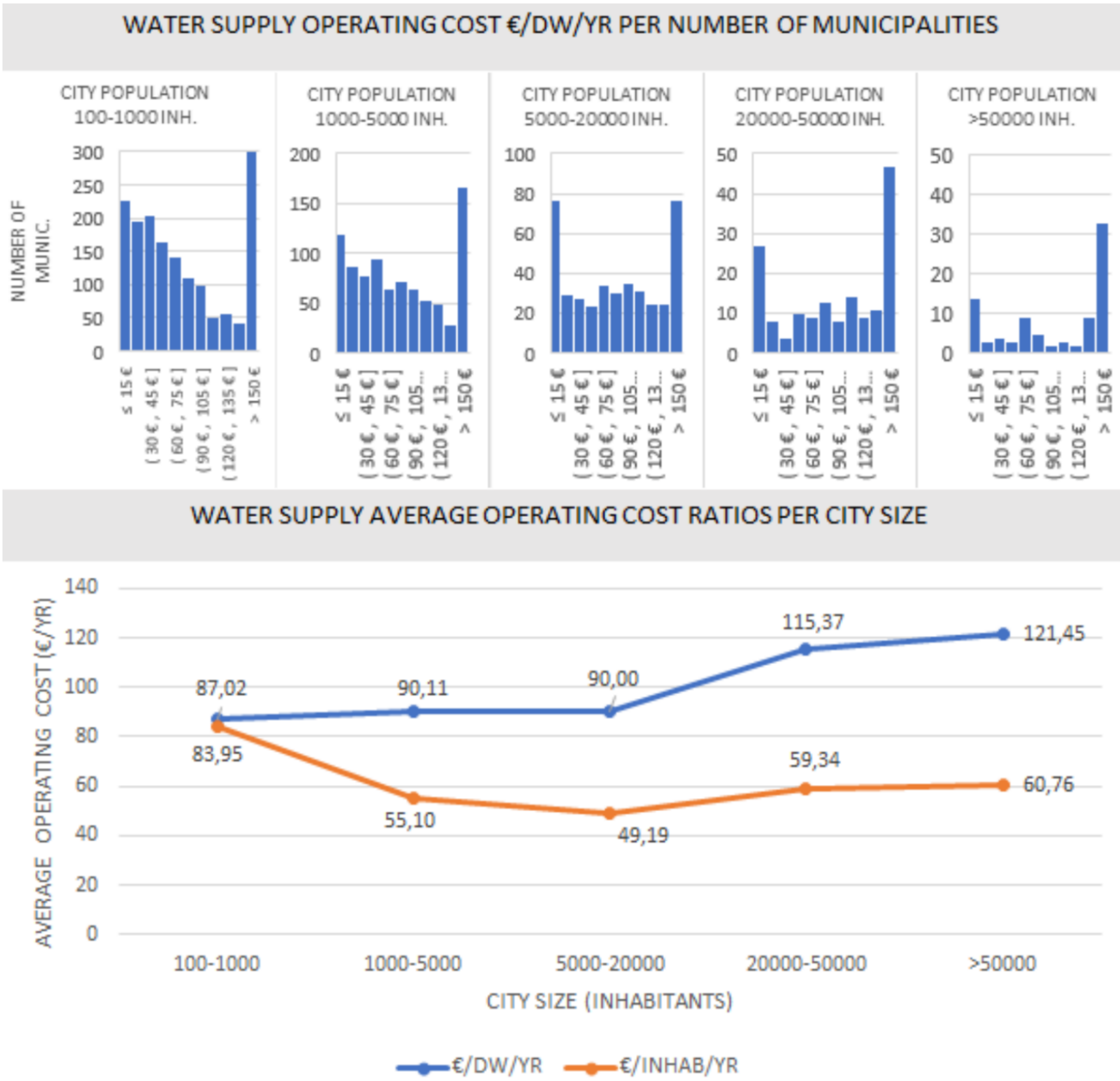


**Figure 2.-** Water supply. Expenditure ratios per inhabitant and per dwelling according to municipal population

## *Sewage and sanitation*

The results obtained for sewage and water sanitation are quite similar to those for the water supply, with the nuance that the relative maximum in per capita spending in the smaller municipalities is far less significant, and the results for the cities between 1.000 and 50.000 inhabitants are quite similar (Figure 3). Instead, the cost per dwelling follows a monotonous increasing function, with a relative variation of almost 100% between the smaller and larger cities.

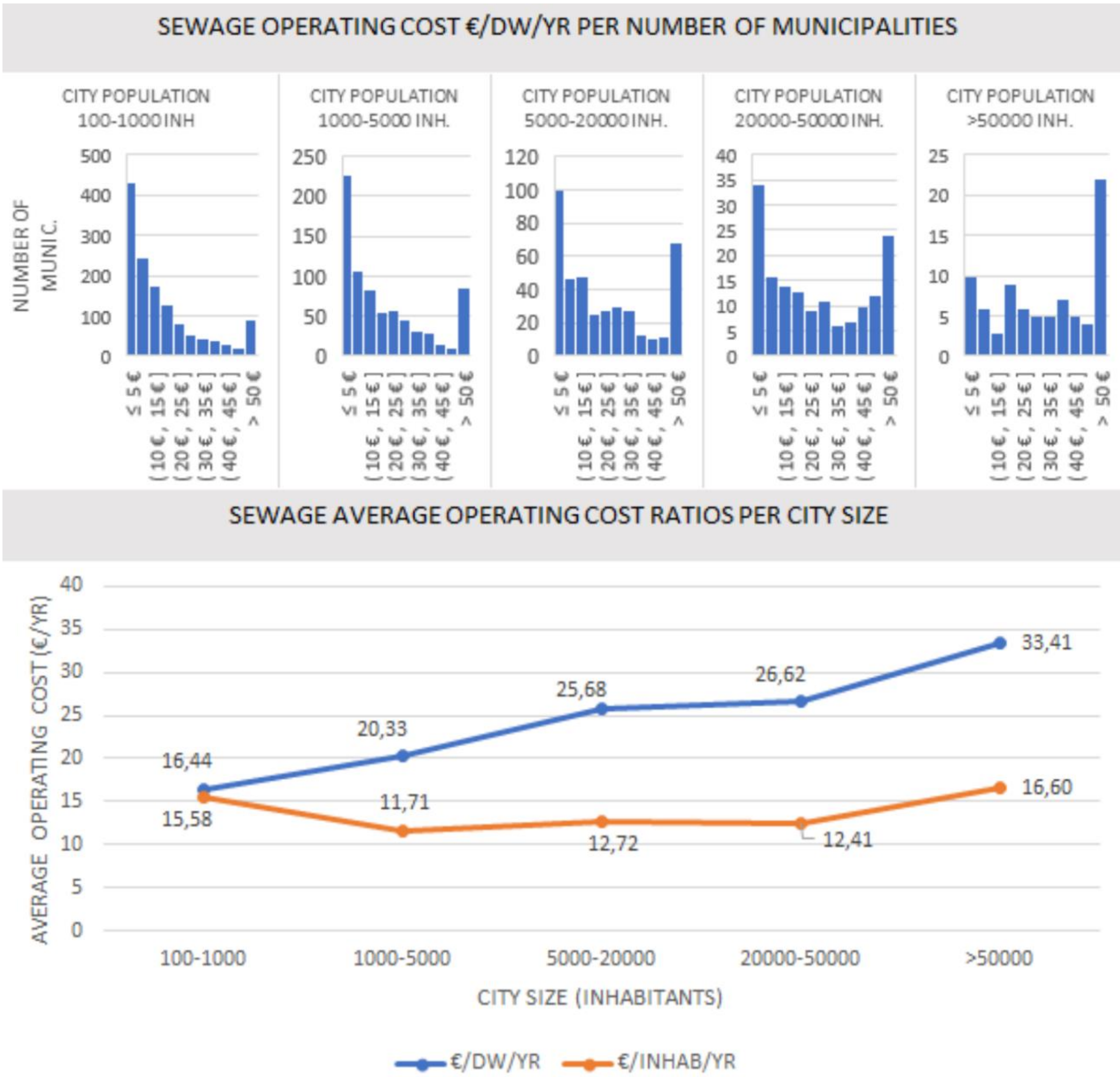


**Figure 3.-** Sewage and sanitation. Expenditure ratios per inhabitant and per dwelling according to municipal population

***Waste collection and disposal***

Among the services analyzed, probably waste collection and disposal is the one with the greatest uncertainty, since the *proxy* variable, the number of dwellings of the city, is not capable of capturing the incidence of the distance traveled by the collection trucks (Ohlsson 2003). As is shown in Figure 4, the result obtained is somewhat erratic, with a pronounced maximum in municipalities with populations between 20.000 and 50.000 inhabitants. This maximum is very difficult to explain, considering that it appears in both ratios. Apart from this value, the most outstanding result is that the cities with populations under 1.000 inhabitants again have the lowest spending level per dwelling and the highest per inhabitant, boosted by the significant ratio of dwellings per inhabitant.

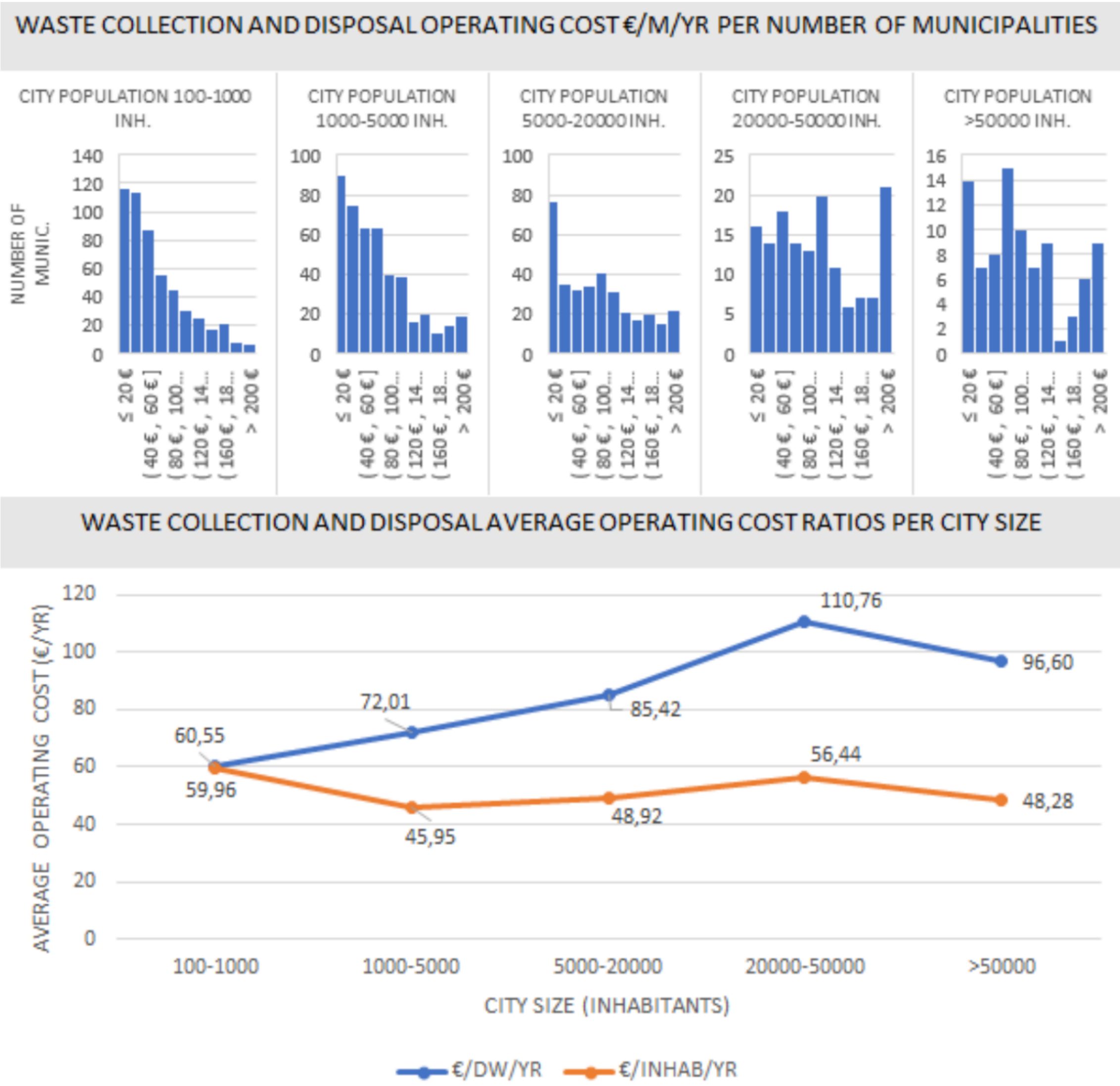


**Figure 4.-** Waste collection and disposal. Expenditure ratios per inhabitant and per dwelling according to municipal population

### *Parks and gardens maintenance*

The results obtained for this service are different compared to other services, since it is the only one where a "U" shape curve in the per capita spending -with two very pronounced peaks under 1.000 and above 50.000 inhabitants- is combined with a decreasing operating cost per unit area as the city size grows (Figure 5). In this case, the increase in per capita spending in large cities is not enough to compensate for the greater proportion of open spaces in the main population centers, which leads to a decrease in investment per landscaped area. If it is considered that this is a very labor-intensive service (Tempesta 2015), a significant drop in the level of service can be predicted in cities with more than 50.000 inhabitants.

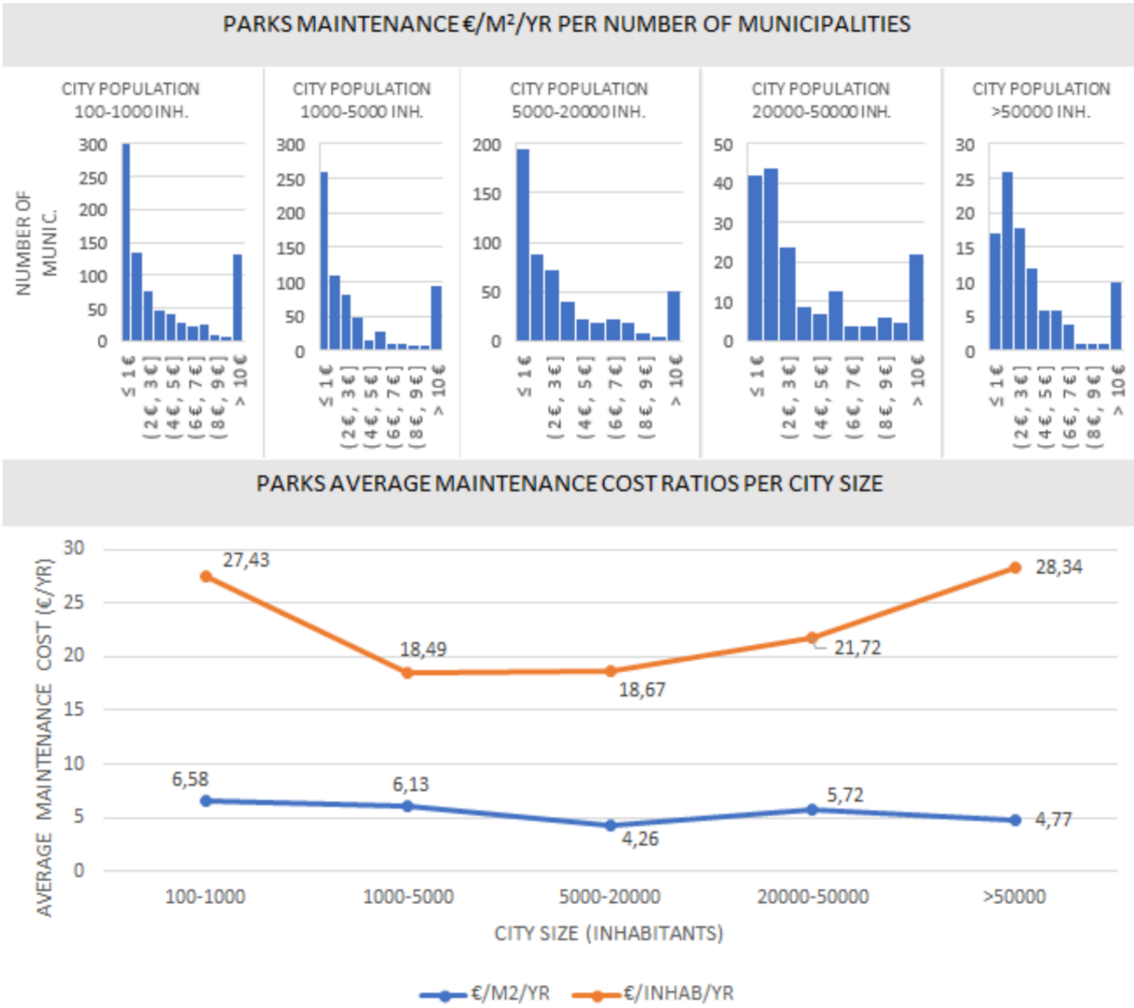


**Figure 5.-** Parks and gardens maintenance. Expenditure ratios per inhabitant and per parks and gardens area according to municipal population

### *Street cleaning*

The analysis of the street cleaning service is usually very complex, since this service can be composed of a set of very different operations and frequencies, which may vary significantly not only between municipalities, but also between roads with different functions and locations within the same city (Calabrò, Komilis 2019). For this service, the operating cost per inhabitant presents a marked "U" shape, with a very evident minimum between cities ranging from 1.000 to 20.000 inhabitants (Figure 6). Instead, the operating cost per unit of street area follows a totally different trend, increasing by around 100% when the city population exceeds 20.000 inhabitants (from € 2/m$^2$ to € 4/m$^2$).

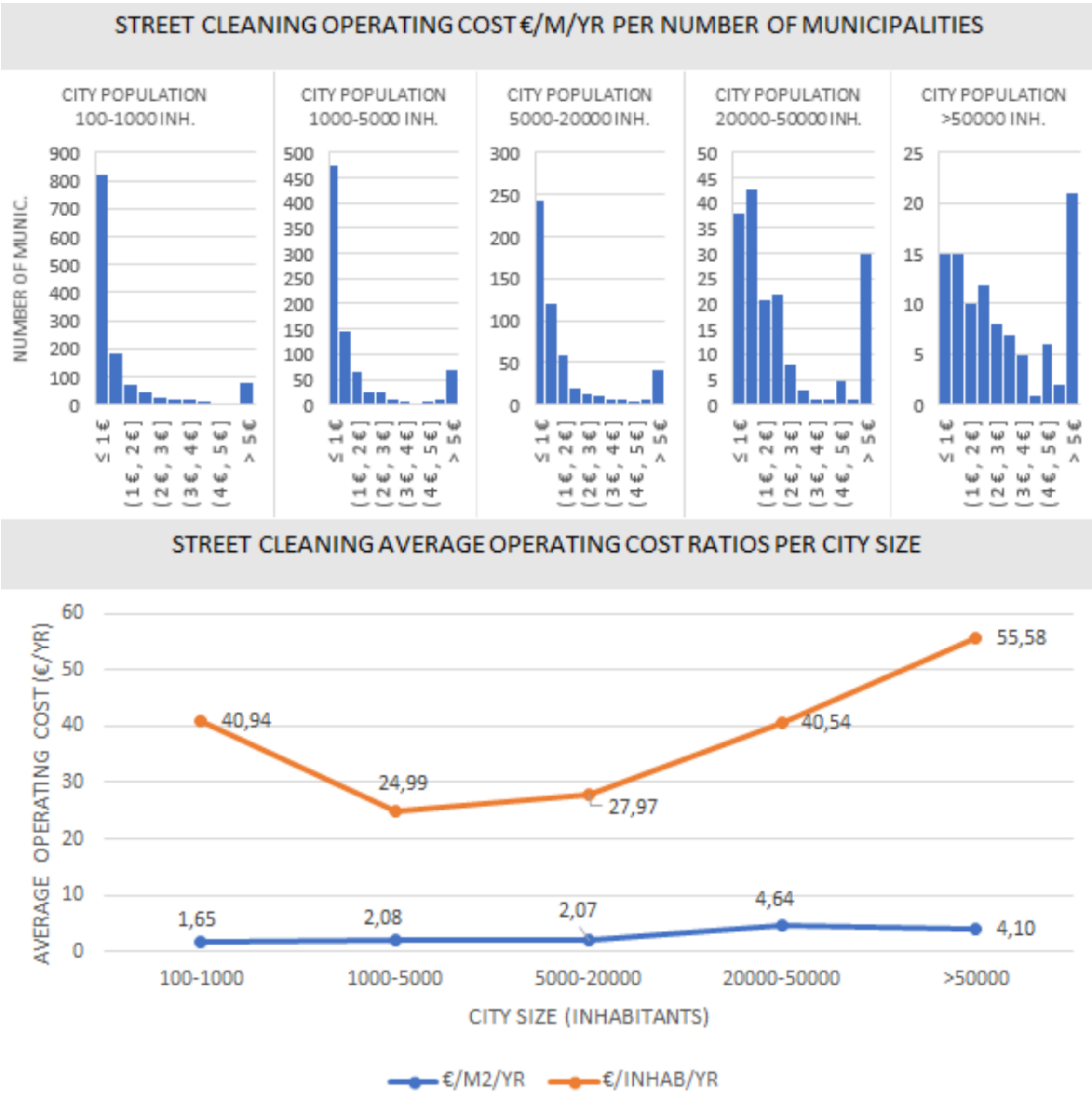


**Figure 6.-** Street cleaning. Expenditure ratios per inhabitant and per street area according to municipal population

The results for the two extreme city sizes are significant in this service. As usual, the higher infrastructure ratio penalizes the fiscal effort of the smallest municipalities. However, in the case of municipalities with over 50.000 inhabitants, the increase by 37% in per capita expenditure regarding those with populations between 20.000 and 50.000

inhabitants is not fully reflected in the operating cost per unit of street area, which falls from € 4,64/m2/year to € 4,10 €/m2/year. Probably, large cities are penalized by a very high level of service in certain zones of the city (Hastings 2007). However, due to the nature of this service, many uncertainties still remain to be solved from the results.

***Pavements maintenance***

For pavements maintenance, the evolution of both spending ratios is remarkably different (Figure 7). Whilst the expenditure per inhabitant decreases sharply when the city size grows (following a quadratic function), the operating cost per unit of street area monotonously increases with a marked peak in larger municipalities (€ 11.41 /$m^2$ compared to € 4.24/$m^2$ in towns with population ranging from 20.000 to 50.000 inhabitants), all driven by the typical decline in the ratio of road infrastructure in large cities (Levinson 2012). This increase in the operating cost per unit of infrastructure might be due to the greater maintenance needs boosted by the traffic pressure in large cities rather than an improvement in the level of service (Tsekeris, Geroliminis 2013; Chang et al. 2017).

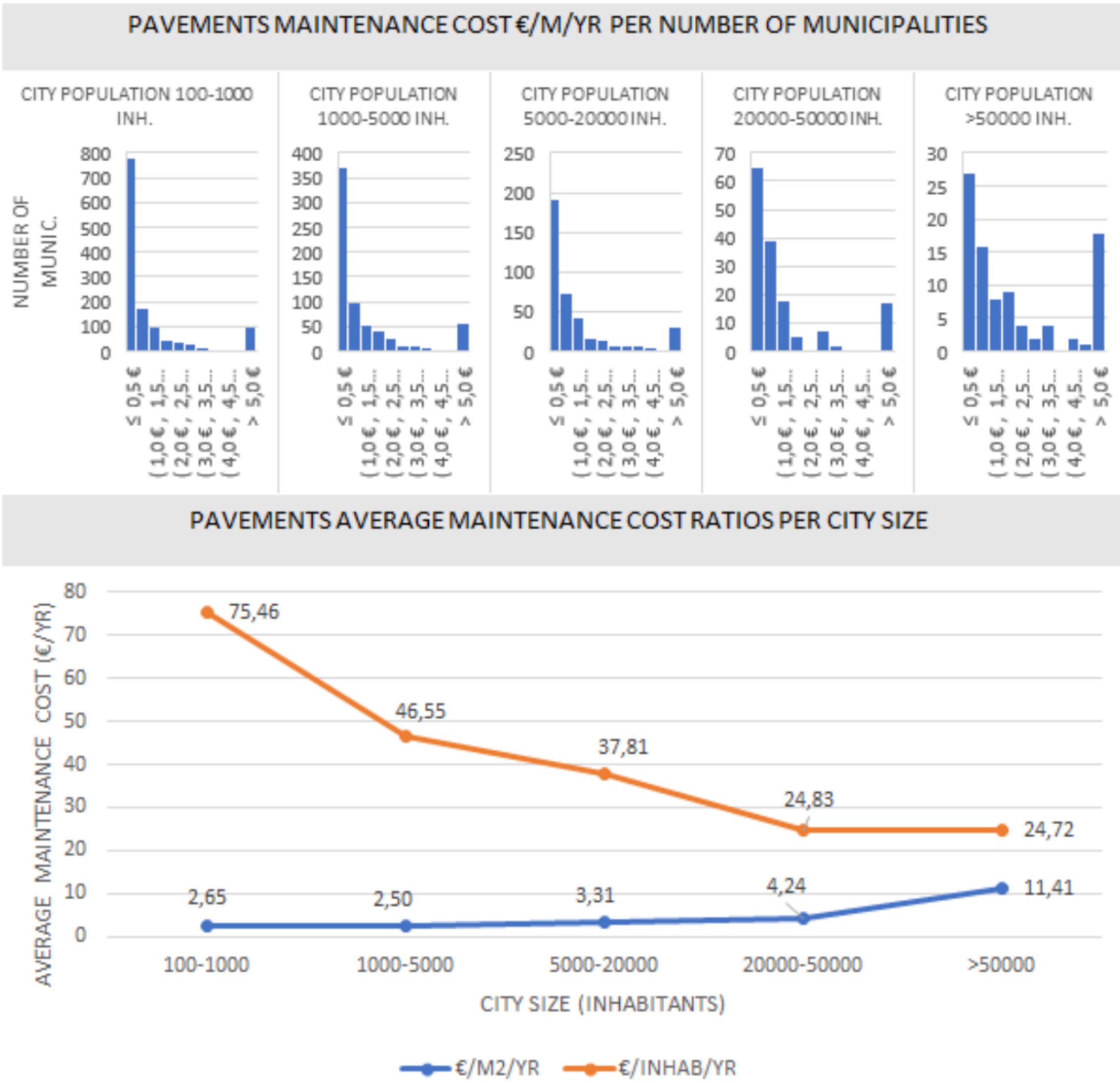


**Figure 7.-** Pavements maintenance. Expenditure ratios per inhabitant and per street area according to municipal population

## Optimal city size and robustness analysis

As shown, the classification of municipalities according to population ranges facilitates the analysis. Moreover, if the results obtained for the set of services are to be integrated into a comprehensive analysis, two results arise. On the one hand, it is possible to approximate the optimal size of the municipality from the per capita operating cost (the only ratio which allows comparing among all the services) of the set of property-oriented services analyzed, and, on the other hand, it allows to check whether the discrete analysis performed according to Spanish Local Act population cohorts has biased the results.

Thus, for the sample municipalities, the correlation between the current annual per capita spending for the set of services analyzed and their population is shown in Figure 8:

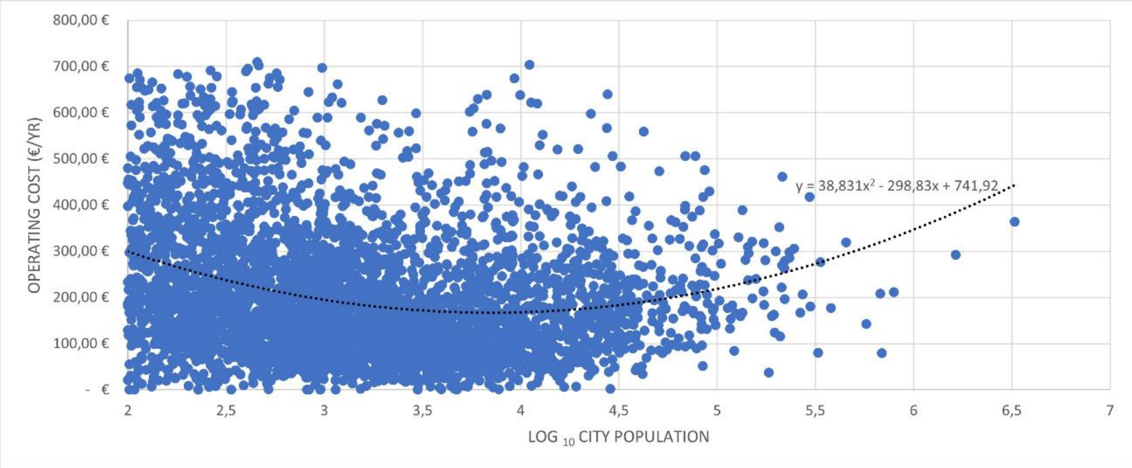


**Figure 8.-** Relationship between city population and per capita operating cost of property-oriented public services

The comprehensive analysis confirms that the current per capita expenditure function follows a "U" shape, with a minimum of around 7.000 inhabitants and a maximum in municipalities with a population below 1.000 inhabitants; these results are consistent with those obtained through the analysis by population cohorts. In addition, this analysis has allowed to qualify the results within the wide cohort of municipalities with a population above 50.000 inhabitants. In this range of population, a sustained increase in operating cost is observed as the population grows, reaching in the municipalities with 500.000 inhabitants the same operating cost than those with less of 1.000 inhabitants. It should be noted that the total expenditure values in Figure 8 are somewhat lower than those obtained in the per-service study, since to carry out the comprehensive analysis it is not possible to eliminate the null results for certain services in many municipalities. However, this difference does not distort the conclusions either on the optimal city size or on the role of the variables involved.

## DISCUSSION

Apart from the results obtained for each service individually, the study has shown that there is a correlation between the unit operating cost of those urban public services involving the operation of a physical infrastructure and the number of inhabitants in the municipality. Thus, in the case of Spanish municipalities for the services of water cycle, public lighting, waste collection and disposal, street cleaning and parks and roads maintenance, the aggregate per capita operating cost function would have a “U” shape, with a maximum in large cities and municipalities below 1.000 inhabitants, as well as an extensive minimum in cities between 5.000 and 20.000 inhabitants (there is barely a 5% difference in public spending within this range of population). According to aggregate operating cost function, total spending per inhabitant falls by 35% in municipalities of 1.000 inhabitants compared to those with 100 inhabitants, and 14% in cities with 5.000 inhabitants compared to those with 1.000 inhabitants. Above approximately 20.000 inhabitants, operating cost grows steadily. This result is consistent with other wide-range studies such as those conducted by Breunig and Rocaboy (2008) for French cities and Soukopová et al. (2014) for Czech Republic municipalities, where a “U” shaped expenditure function was also obtained. The result is also similar to the study of Solé-Ollé and Bosch (2005) for Spanish municipalities, where the minimum annual current expenditure per inhabitant was found in cities with around 5.000 inhabitants. It is interesting that the expenditure function shape is similar in all these studies regardless of the set of services analyzed (mixture of property and people-oriented or only property services). Future research should delve into this aspect since apparently there exists a similar pattern in the relationship between city population and operating cost even in public services of a very different nature. It is necessary to insist that the result shows the lowest level of fiscal effort to supply the set of basic services analyzed, but not the highest level of efficiency, which is closely related to the level of service (expenses per unit of infrastructure/service) not aggregable due to the differences between the outcome units.

Apart from the operating cost expenses as a function of city population, the study has tried to explore whether among those determinants of public spending correlated with the city size, any of them contribute significantly to the result obtained. In this sense, the combined analysis of the operating expenditure ratios per capita, per unit of service/infrastructure (proxy of the level of service) and the infrastructure ratio per inhabitant (proxy of the city compactness) has allowed to highlight not only that both factors are linked to city population, but also that they play a paramount role in relation to public spending at least for the set of services analyzed. This does not mean that they are the only factors involved, but, due to the consistence of some trends, both should be carefully implemented in this kind of studies.

Thus, regarding the ratio of infrastructure/service per inhabitant, a *proxy* for the global compactness of the urban pattern, the study has not only shown that the densest areas are only found in the largest cities (Holcombe, Williams 2008), but also lower ratios of infrastructure and urbanized area per inhabitant than smaller municipalities (Fuller, Gaston 2009). This fact, which might be the result of factors such as the progressive abandonment of small rural urban areas, with high vacant dwelling rates (Jurado, Pazos-García 2016), or the price speculation in large cities (Bertaud 2006), has been observed in all the services analyzed with the exception of green areas, where, contrary to other studies, higher ratios of parks and gardens have been obtained in the largest cities (Richards et al. 2017). This result shows the importance of implementing accurate *proxies* for the urban pattern and confirms the findings of those studies about municipalities merging where, not the population, but the “plant size”, has been found as the key variable for the operating cost of most of public services (King, Ma 2000; Blom-Hansen et al. 2016; Roesel 2017).

As does the dispersion of infrastructure throughout the territory, the combined analysis of the three ratios has highlighted that the level of service not only plays a crucial role in public spending (Duncombe, Yinger 1993), but it is also quite correlated with city population. Represented in this study by the ratio of expenditure per unit of infrastructure, it has been observed that this ratio usually grows as the city population does, although there are some exceptions in cities with population above 50.000 inhabitants. Although this *proxy* does not allow to identify what part of the operating cost is destined to improve the level of service (outcome), and what part is diluted in higher salaries (Tiebout 1956; Moomaw, Shatter 1996) or even in a greater inefficiency of public administration in large cities (Boyne 1996; King, Ma 2000), the level of correlation with city population obtained is significant enough for it to be advisable to be integrated in this kind of studies.

Several lessons for both urban planning practice and the management of future urban dynamics can be extracted from the results of the study. Thus, depending on their population, medium-sized municipalities should manage future growth in a different way. For example, although it is always necessary to consider all the circumstances involved, in cities with population under 5.000 inhabitants any population increase should be led towards the densification of the existing urban settlements since, as can be deduced from Table 4, a lower fiscal effort compatible with a potential improvement in public service levels could be obtained. In this type of municipalities, usually with an oversized public service infrastructure in relation to their population, it would not make sense to insist on low-density urban patterns harmful for the economic management of the urban public services. Of course, if it is the case of a municipality with a significant number of vacant dwellings due to a shrinking process, the first option would be the intensive use of the existing buildings.

In the case of the municipalities with population over 50.000 inhabitants the situation is somewhat more complex, since the operating cost per capita of basic public services increases proportionally more rapidly than population does (Figure 8). In this context, from Table 4, it could be deduced that, if the city grows both in population and area maintaining the same pre-existing infrastructure ratios (the same urban pattern and housing density), only per capita spending on waste collection and disposal would improve, whilst the unit operating cost of the rest of public services would increase without a better level of service. Thus, the expansion in area of the city would not be advantageous for the economic management of its public infrastructures and, in addition, it would be less resilient against potential population decreases. Instead, if the population growth is lead to renewal operations with a densification of the existing urban settlements, the operating cost of the fixed infrastructure would remain the same, providing the municipality the possibility to opt both for the increase of the public service levels without an increasement of the tax burden or for a fiscal pressure reduction, thus increasing the economic competitiveness of the city as a whole. Obviously, new urban developments with a lower density than preexisting or a sprawl urban pattern would be contraindicated, since in that case both per capita spending levels and service levels could worsen.

As can be observed, with the nuances indicated, the results of this study are aligned with those others that indicate that, in general, from the point of view of the economic management of urban public services, urban renewal and densification is usually more advantageous than the expansion of the urban settlements (OFDT 2000; Tonkin 2008). Notwithstanding, it is necessary to take into account that the densification of any existing urban pattern can be very complex due to the number of factors involved (Haaland, van den Bosch 2015; Nachmany, Hananel 2023).

Finally, it should be noted that a study of this scale and scope is subject to several limitations. Apart from those indicated in the Methodology section (lack of external control of the data provided for municipalities, etc.), it is necessary to consider that the expenditure patterns obtained for Spanish municipalities might not be exportable to other areas with urban patterns very different to the Mediterranean city ones. However, the main limitations could come from the fact that the two main variables analyzed, the urban pattern and the level of service have been represented through two proxies such as the amount of infrastructure per inhabitant and the operating cost per unit of infrastructure respectively, which, especially in the latter case, might be subject to numerous nuances.

Therefore, the combined use of per capita and per unit of infrastructure ratios to analyze the economic efficiency of urban settlements according to their population has allowed to delve in the role of the urban pattern and the level of service from a new perspective, complementing the usual econometric studies in this filed where sometimes poor *proxy* are used to consider these variables.

## CONCLUSIONS

The study has confirmed that the concurrence of a significative number of physical, social or administrative variables complicates any analysis of the urban economic dynamics, leading to very few certainties. In this sense, this study has focused on the analysis of the relationship between the city population and the unit operating cost of its basic property-oriented services, showing a higher per capita expenditure ratio in the largest (> 50.000 inhabitants) and smallest (< 1.000 inhabitants) municipalities. As a result of the concurrence of all the operating municipal cost determinants, the minimum spending ratio per inhabitant in Spanish municipalities would be in the range of 5.000-20.000 inhabitants, with a minimum unit operating expenditure around 7.000 inhabitants. As indicated, this is not equivalent to efficiency since this concept involves a qualitative factor as the level of service reached with that fiscal burden.

The combined analysis of the ratios of operating cost per capita and per inhabitant, as well as the ratio of infrastructure/service per inhabitant has not only highlighted that two of them, as did the level of service and the urban pattern, play a paramount role in the operating cost of the basic public services, but also that they are significantly correlated with the city population. Thus, both can help to highlight that the greatest fiscal effort measured in the largest and smallest municipalities has a different origin. Thus, while in smaller municipalities the high ratios of per capita spending on basic public services would be provoked by high ratios of infrastructure per inhabitant, ergo, by less compact urban patterns, in the largest cities the reason would be higher levels of expenses per unit of infrastructure, probably linked to a better level of service.

Be it as it may, further future research is necessary in this field. As indicated, although the ratios of infrastructure per inhabitant and spending per unit of infrastructure might be good *proxies* for the urban pattern and the level of service respectively, and although they can contribute to explain some public expenses dynamics, they are not exempt of limitations. Thus, it would be necessary to deepen the analysis of what part of the municipal expenses becomes an outcome and what part is lost in “system frictions”. In addition, the relationship between compactness and city population observed in Spanish municipalities might not be a global pattern.

## STATEMENTS AND DECLARATIONS

The authors report there are no competing interests to declare

## DATA AVAILABILITY STATEMENT

All data used during the study are available in the Database of the Effective Cost of Public Services Provided by Local Entities elaborated by the Spanish Ministry of Finance (2019). URL: https://serviciostelematicosext.hacienda.gob.es/sgcief/Cesel/Consulta/Consulta.aspx

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